

ELECTRIC AND FLUIDIC CABLES

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority to U.S. Provisional Patent Application Nos. 63/274,829, filed November 2, 2021, and 63/275,278, filed November 3, 2021, both of which are hereby incorporated by reference in their entirety.

TECHNICAL FIELD

[0002] The present disclosure relates to cables configured to allow both electrical wiring and fluids to safely and securely be passed through the cable, such as to an intravascular blood pump used to support flow in a patient's blood vessel.

BACKGROUND

[0003] Present day medical treatments, such as cardiovascular treatments, may involve the use of numerous medical devices, fluid lines, and the like. These fluid lines may provide, *e.g.*, necessary fluid to the patient, may be removing or recirculating fluids from the patient (such as blood), or may be providing fluid needed by a medical device, such as a purge fluid. For example, in some blood pumps, a purge fluid may be deployed to keep blood from entering the pump mechanism and to mitigate the effects of blood and/or bio-deposit buildup on the pump mechanisms.

BRIEF SUMMARY

[0004] According to a first aspect of the present disclosure, a cable may be arranged to operably connect a blood pump to a controller, where the cable may include a first tubular body defining a first lumen therethrough, a tubular purge body disposed within the first lumen and extending along at least a portion of a length of the first lumen, the tubular purge body defining a purge lumen arranged to transfer a fluid therethrough, and at least one tubular electrical wire body disposed within the first lumen, each tubular electrical wire body defining an electrical wire lumen therethrough for receiving one or more electrical wires.

[0005] In some embodiments, the first tubular body may comprise a plurality of layers, such as an inner binder layer and an outer jacket. In some embodiments, the inner binder layer may comprise or consist of polytetrafluoroethylene (PTFE), the outer jacket may comprise or consist of a thermoplastic polyurethane, or a combination thereof. Filler may be present within the first lumen and may be disposed around at least a portion of the tubular purge body and the

tubular electrical wire body. In some embodiments, the filler comprises or consists of polytetrafluoroethylene (PTFE).

[0006] In some embodiments, the tubular purge body may comprise a plurality of layers, such as an inner binder layer and an outer jacket. In some embodiments, the inner binder layer may comprise or consist of polytetrafluoroethylene (PTFE), the outer jacket may comprise or consist of a thermoplastic polyurethane, or a combination thereof.

[0007] In some embodiments, a proximal portion of the tubular purge body may be operably connected to an input connector, where the input connector may be configured to provide a sterile attachment to a fluid source. In some embodiments, the fluid source may be removably attachable from the input connector. In some embodiments, the proximal portion of the tubular purge body may be connected to a pressure storage set (PSS) assembly which may comprise or be operably connected to the input connector.

[0008] In some embodiments, the tubular purge body may be configured to extend through the first lumen from the distal end of the first tubular body to the proximal end of the first tubular body. In some embodiments, openings in the first tubular body may be created to allow the tubular purge body to pass through a sidewall of the first tubular body at an intermediate location. In some embodiments, the first tubular body may comprise an outer surface defining a first opening extending through a sidewall to an inner surface of the first tubular body, the inner surface defining the first lumen, the tubular purge body configured to enter the first lumen through the first opening.

[0009] Various configurations of internal cable organization may be utilized. In some embodiments, a plurality of tubular electrical wire bodies may be present, including a first tubular electrical wire body and a second tubular electrical wire body. In some embodiments, the first tubular electrical wire body may be configured to receive at least one electrical wire in electrical communication with a motor. In some embodiments, a plurality of electrical wires may extend through the electrical wire lumen of one or more of the at least one tubular electrical wire bodies. In some embodiments, a plurality of electrical wires may extend through each electrical wire lumen. In some embodiments, at least one electrical wire extending through a second tubular electrical wire body may be in electrical communication with a sensor. In some embodiments, all electrical wires are within a single tubular electrical wire body. In some embodiments, each tubular electrical wire body may contain the same number of electrical wires. In some embodiments, a number of electrical wires in the first tubular electrical wire body may be different from a number of electrical wires in the second tubular electrical wire body. In some embodiments, the first tubular electrical wire body contains 2-4 electrical wires,

and the second tubular electrical wire body contains 3-5 electrical wires. In some embodiments, one or more of the electrical wires may comprise copper. In some embodiments, each electrical wires may comprise copper. In some embodiments, each electrical wire may comprise or consist of copper surrounded by an electrically insulating sheath. In some embodiments, filler may be disposed around at least a portion of at least one electrical wire.

[0010] In some embodiments, the cable may also contain a tubular optical fiber body within the first lumen, where the tubular optical fiber body defines an optical fiber lumen therethrough. In some embodiments, the tubular optical fiber body may comprise or consist of polytetrafluoroethylene (PTFE).

[0011] In some embodiments, the cable may extend from a controller to a handle (*e.g.*, a handle for controlling an insertable or implantable medical device). In some embodiments, the controller is configured to control a fluid flowing through a purge lumen extending through the cable, receive optical data through an optical fiber slidably positioned within the optical fiber lumen, and control a motor through at least one electrical wire.

[0012] In some embodiments, the cable may also comprise a first overmold, which is connected to a portion of the first tubular body at a location distal to an opening defined by an outer surface of the first tubular body extending to the first lumen and connected to a portion of both the first tubular body and the first tubular body at a location proximal to the defined opening. In some embodiments, the cable may also comprise a second overmold, the second overmold connected to a portion of the first tubular at a location proximal from the first overmold.

[0013] The cable may also comprise a case configured to surround at least a portion of the first tubular body proximal to the first overmold, the case may be configured to connect to the first overmold such that any component surrounded by the case cannot be twisted, pulled apart, or pushed apart.

[0014] In some embodiments, the case may be a two-part case, which may comprise or consist of a polycarbonate. In some embodiments, a first part (*e.g.*, first body) of the two-part case may be configured to connect to a second part (*e.g.*, second body) of the two-part case by inserting one or more pins on the first part into a corresponding boss on the second part, and by one or more raised portions on an internal surface of the first part interface with a plurality of depressions on an external surface of the second part. In some embodiments, the case may be configured to define a first port surrounding a first overmold, a second port for the first tubular body distal from a second overmold and proximal from the first overmold, and a third

port for allowing a fluid source to operably connect to the tubular purge body through an input connector.

[0015] According to a second aspect of the present disclosure, a system may comprise a controller, a pump, and a cable as described previously, where the cable operably connects the pump to the controller. In some embodiments, the cable may extend from a handle to the controller.

[0016] According to a third aspect of the present disclosure, an overmold may be provided for a first tubular body defining a first lumen therethrough, the first tubular body having a second tubular body within the first lumen, the second tubular body defining a second lumen therethrough, the second tubular body configured to enter the first lumen through an opening defined by an outer surface of the first tubular body and extending to the first lumen. The overmold may comprise a distal portion connected to a portion of the first tubular body at a location distal to the defined opening, and a proximal portion connected to a portion of both the first tubular body and the second tubular body at a location proximal to the defined opening, where the proximal portion is configured to connect to a case such that the case cannot twist, push, or pull apart from the overmold.

[0017] In some embodiments, the case may be a two-part case comprising a first part and a second part, where the first part is in contact with a first portion of the overmold, and the second part is in contact with a second portion of the overmold.

[0018] In some embodiments, the first tubular body may comprise a plurality of layers, such as an inner binder layer and an outer jacket. In some embodiments, the inner binder layer may comprise or consist of polytetrafluoroethylene (PTFE), the outer jacket may comprise or consist of a thermoplastic polyurethane, or a combination thereof. Filler may be present within the first lumen and may be disposed around at least a portion of the second tubular body and at least one additional tubular body extending through at least a portion of the first lumen. In some embodiments, the filler comprises or consists of polytetrafluoroethylene (PTFE).

[0019] In some embodiments, the second tubular body may comprise a plurality of layers, such as an inner binder layer and an outer jacket. In some embodiments, the inner binder layer may comprise or consist of polytetrafluoroethylene (PTFE), the outer jacket may comprise or consist of a thermoplastic polyurethane, or a combination thereof.

[0020] In some embodiments, a proximal portion of the second tubular body may be operably connected to an input connector, where the input connector may be configured to provide a sterile attachment to a fluid source. In some embodiments, the fluid source may be removably attachable from the input connector. In some embodiments, the proximal portion of the tubular

purge body may be connected to a physiological saline solution (PSS) assembly which may comprise or be operably connected to the input connector.

[0021] In some embodiments, at least one additional tubular body may extend through the first lumen from a proximal end to a distal end, each additional tubular body defining a lumen extending therethrough. In some embodiments, the at least one additional tubular body may comprise a plurality of additional tubular bodies, including a first additional tubular body defining a first additional lumen and a second additional tubular body defining a second additional lumen. In some embodiments, at least one electrical wire may extend through one or more of the at least additional tubular bodies.

[0022] In some embodiments, one or more electrical wires may be in electrical communication with a motor. In some embodiments, at least one electrical wire may extend through the second additional tubular body, and one of those electrical wires may be in electrical communication with a sensor.

[0023] In some embodiments, the first and second additional tubular bodies may be configured to receive the same number of electrical wires. In some embodiments, a number of electrical wires in the first additional tubular body may be different from a number of electrical wires in the second additional tubular body. In some embodiments, the number of electrical wires in the first additional tubular body may be 2-4, and the number of electrical wires in the second additional tubular body may be 3-5. In some embodiments, a plurality of electrical wires may extend through one of the at least one additional tubular body. In some embodiments, a plurality of electrical wires may extend through each additional tubular body. In some embodiments, one or more of the electrical wires may comprise copper. In some embodiments, each electrical wires may comprise copper. In some embodiments, each electrical wire may comprise or consist of copper surrounded by an electrically insulating sheath. In some embodiments, filler may be disposed around at least a portion of at least one electrical wire.

[0024] In some embodiments, the at least one additional tubular body may comprise a tubular optical fiber body defining an optical fiber lumen configured to slidably receive an optical fiber therethrough. In some embodiments, the optical fiber lumen is configured to slidably receive a plurality of optical fibers therethrough.

[0025] In some embodiments, the first tubular body may extend proximally from a handle. In some embodiments, the first tubular body may extend from a handle to a controller, where the overmold may be positioned between the handle and the controller. In some embodiments, the controller may be configured to control a fluid flowing through the purge lumen, receive optical

data through an optical fiber slidably positioned within the optical fiber lumen, and control a motor through at least one electrical wire.

[0026] According to a fourth aspect of the present disclosure, a case, such as a two-part case, may be configured to contain a PSS assembly and clamp around an overmold, where the overmold surrounds a portion of a first tubular body and a second tubular body, the second tubular body being connected to the PSS assembly. In some embodiments, the case may be arranged to chemically and/or mechanically protect the PSS. For example, in some embodiments, the case may facilitate user interaction with the PSS.

[0027] In some embodiments, the case may include two bodies that are arranged to engage with one another. For example, the first body of the two-part case may include a pin, a boss, or a combination thereof, and at least one raised portion on an interior surface of the first part. In such an example, the second body of the two-part case may include a pin, a boss, or a combination thereof, and a plurality of depressed portions on an exterior surface of the second body to engage with the first body. Each pin or boss is configured to align with a boss or pin, respectively, on the opposite part, and the at least one raised portion is configured to interact with each depressed portion such that the two parts cannot be pulled apart.

BRIEF DESCRIPTION OF DRAWINGS

[0028] Figure 1 is a depiction of an embodiment of a prior art system.

[0029] Figure 2A is a depiction of an embodiment of a disclosed cable within a system.

[0030] Figure 2B is a depiction of an additional embodiment of a disclosed cable within a system.

[0031] Figures 3A-3E are cross-sectional views of various embodiments of a disclosed cable.

[0032] Figure 4A is a cross-sectional side view of an embodiment of a first overmold.

[0033] Figure 4B is a cross-sectional side view of an embodiment of a first and second overmold.

[0034] Figure 5A is a depiction of an embodiment of a cable, overmold, and case.

[0035] Figure 5B is a depiction of an embodiment of a first part of a two-part case.

[0036] Figure 5C is a depiction of an embodiment of a second part of a two-part case.

[0037] Figure 5D is a cross-sectional view of an embodiment of a snap fit connection between a first part and a second part of a two-part case.

[0038] Figure 6 is an exploded view of an embodiment of a cable, overmold, and case.

[0039] Figure 7 is an exploded view of an embodiment of a cable and a case.

[0040] Figure 8 is an exploded view of an embodiment of a cable, an overmold, and a case.

[0041] Figure 9 is an exploded view of an embodiment of a cable and a case.

[0042] Figure 10 is an exploded view of an embodiment of a cable, and a case.

[0043] Figures 11A and 11B are exploded views of an embodiment of a cable and a case.

[0044] Figure 12 is a perspective view of a case according to one embodiment.

[0045] Figures 13A and 13B are a depiction of an embodiment of a case.

DETAILED DESCRIPTION

[0046] Embodiments of the present disclosure are described in detail with reference to the figures wherein like reference numerals identify similar or identical elements. It is to be understood that the disclosed embodiments are merely examples of the disclosure, which may be embodied in various forms. Well known functions or constructions are not described in detail to avoid obscuring the present disclosure in unnecessary detail. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a basis for the claims and as a representative basis for teaching one skilled in the art to variously employ the present disclosure in virtually any appropriately detailed structure.

[0047] Blood pumps of different types are known, such as axial blood pumps, centrifugal blood pumps, or mixed-type blood pumps, where the blood flow is caused by both axial and radial forces. One such example of a blood pump is the Impella® line of blood pumps (*e.g.*, Impella 2.5®, Impella CP®, Impella 5.5®, *etc.*), which are products of Abiomed Inc. of Danvers, MA. Intravascular blood pumps may be inserted into a patient's vessel, such as via the aorta, by means of a catheter.

[0048] Such blood pumps may involve the use of numerous medical devices, fluid lines, and the like. These fluid lines may be providing, *e.g.*, necessary fluid to the patient, may be removing or recirculating fluids from the patient (such as blood), or may be providing fluid needed by a medical device, such as a purge fluid. For example, in some blood pumps, a purge fluid may be deployed to keep blood from entering the pump mechanism and to mitigate the effects of blood and/or bio-deposit buildup on the pump mechanisms.

[0049] In existing systems, see, *e.g.*, FIG. 1, a blood pump assembly **1200** may include a blood pump **1210** fluidically connected to a purging device **1250**. The blood pump assembly **1200** also may include a controller **1230** (*e.g.*, an Automated Impella Controller® from Abiomed, Inc., Danvers, MA), a display **1240**, a connector cable **1260**, a plug **1270**, and a repositioning unit **1280**. As shown, the controller **1230** may include a display **1240**. Controller **1230** may monitor and controls blood pump **1210**. During operation, purging device **1250** may deliver a purge fluid to blood pump **1210** through catheter tube **1217**, such as to prevent blood from

entering the motor (not shown) within motor housing **1216**. In some implementations, the purge fluid comprises a dextrose solution (*e.g.*, 5% dextrose in water with 25 or 50 IU/mL of heparin). Connector cable **1260** may provide an electrical connection between blood pump **1210** and controller **1230**. Plug **1270** connects catheter tube **1217**, purging device **1250**, and connector cable **1260**. In some embodiments, plug **1270** may include a memory for storing operating parameters in case the patient needs to be transferred to another controller. Repositioning unit **1280** may be used to reposition blood pump **1210**. As shown in this view, the fluid line may be separate from the connector cable having one or more electrical wires.

[0050] The inventors have recognized that fluid lines in blood pumps and/or other medical devices may need to remain thin, light, and flexible to be useful during the procedures, but this results in situations where a patient's movements and/or movements of a user such as a medical provider may cause mechanical loads that lead to breakage, separation, or disconnection of some fluid lines, or result in kinks being formed in the fluid lines. A means for overcoming these hurdles is therefore useful and desirable. For example, as described herein, a cable may be configured to fluidically and electrically couple a blood pump and/or another medical device to a controller (or other suitable device). In some embodiments, the cable also may include one or more optical wires to optically connect the blood pump to the controller. As also described herein, the medical device assembly may include a case arranged to protect the PSS and cable. In some embodiments, an overmold may extend over a portion of the cable.

[0051] Referring to FIG. 2A, a system **1** according to one embodiment is depicted, with the system **1** having a controller **30**, a medical device, such as a blood pump **25**, and a cable **10** that operably connects the blood pump to the controller. In such embodiment, as described herein, the cable may be configured to receive fluid and electrical wire(s) through the cable. In some embodiments, the cable also may be configured to receive optical fiber(s) through the cable. The medical device may be, *e.g.*, a catheter-based blood pump. As will be appreciated, the current disclosure is not limited to any particular blood pump or other suitable medical device. In some embodiments, the blood pump **25** may include a catheter **21** and a handle **20**. The fluid, electrical signals, and optionally optical signals may pass from the cable **10** through the handle **20**, through catheter **21**, and to the blood pump **25**. For example, in some embodiments, the fluid may include a purge fluid, and the handle may include a coupling between a purge lumen in the catheter **21** and a purge lumen in the cable **10**. Similarly, in some embodiments, one or more electrical and/or optical connections may be formed within the handle **20** to allow electrical and/or optical signals to pass from the cable **10**, through the handle **20**, and through the catheter **21** to the blood pump **25**. In other embodiments, one or more fluid lumens,

electrical wires, and/or optical fibers may extend continuously from the cable **10**, through the handle **20** and catheter **21**, to the blood pump **25**. Thus, depending on the particular embodiment, the handle **20** may, or may not, include one or more fluidic, electrical, and/or optical connections.

[0052] In some embodiments, the cable may be configured to have a distal end **11** connected to a handle **20** and the proximal end **12** operably connected to an input connector **37**, the input connector configured to provide a sterile attachment to a fluid source. In some embodiments, the fluid source may be removably attached to the input connector. In some embodiments, a proximal end (or proximal portion) of the tubular purge body may be connected to a pressure storage set (PSS) assembly **16** that may comprise the input connector **37**.

[0053] As described herein, the cable **10** may be configured to allow a fluid source **40**, which may be removably attached, to provide fluids to the patient or the blood pump **25** through the cable **10**. In some embodiments, the cable **10** may branch into two separate lines **17**, **18**. The cable **10** may operably connect the pump **25** to the controller **30** through, *e.g.*, one or more connectors **35**, **36**. In some embodiments, the connector **36** may interface with the pressure line (not shown) of a purge cassette. In some embodiments, the system may have an input connector **37** that allows a second line **18** to be removably connected, where the second line may be configured to provide a fluid to the cable. In some embodiments, the first line **17** may electrically and/or optically connect the cable to the controller **30**.

[0054] In some embodiments, the handle may include a case **15** (*see, e.g.*, FIG. 2A) that encompasses at least a portion of the cable **10**. As will be appreciated, the cable may branch into the separate lines which are protected via the case. For example, as shown in FIGS. 6 and 7, branches may be formed independent of the case in which they are housed.

[0055] Referring to FIG. 2B, an alternate system **2** is depicted, where the cable **10** extends from the handle **20** to the controller **30** and connects to the controller via a connector **38**. In some embodiments, the cable may be configured to have the distal end **11** connected to a handle **20** and the proximal end **12** connected or operably connected to an input connector **38**, the input connector configured to provide a sterile attachment to a fluid source. In some embodiments, the fluid source may be removably attached to the input connector.

[0056] Cable

[0057] To enable the cable **10** to contain electrical wiring and allow fluids to pass through the cable simultaneously, cable **10** may advantageously be configured in certain arrangements.

[0058] Referring to FIG. 3A, a cross section of an embodiment of a cable **100** can be seen. Cable **100** may comprise a first, outer, tubular body **110** having a distal end and a proximal end, the first tubular body having an inner surface **113** defining a first lumen therethrough. Cable **100** may also have a fluid line, such as a tubular purge body **120** disposed within the first lumen and extending along at least a portion of a length of the first lumen, the tubular purge body **120** having an inner surface **123** defining a purge lumen arranged to transfer a fluid therethrough. Cable **100** may also have at least one tubular electrical wire body **130** disposed within the first lumen, each tubular electrical wire body having an inner surface **133** defining an electrical wire lumen therethrough for receiving one or more electrical wires **140**.

[0059] As will be appreciated, although the tubular purge body and the tubular electrical wire body is shown as having the same outer diameter, the diameter of the tubular bodies may vary in other embodiments. As will be further appreciated, the tubular purge body and tubular electrical body may have any suitable arrangement in the first tubular body. In some embodiments, the tubular purge body and the tubular electrical body may be attached to one another and/or to the first tubular body, although the tubular purge body and the tubular electrical body may move freely relative to one another in the first tubular body.

[0060] In some embodiments, the first tubular body may have a nominal outer diameter between 3 mm and 8 mm, such as between 5.5 mm – 6.5 mm.

[0061] Referring to FIG. 3B, a cross section of an embodiment of a cable **101** can be seen. In some embodiments, the first tubular body **110** may comprise a plurality of layers **111**, **112**. In some embodiments, this plurality of layers may comprise an inner binder layer **112** and an outer jacket **111**. In some embodiments, the inner binder layer **112** of the first tubular body may comprise or consist of polytetrafluoroethylene (PTFE) and the outer jacket **111** of the first tubular body may comprise or consist of a thermoplastic polyurethane.

[0062] In some embodiments, a cable may also comprise filler **190** within the first lumen. The filler may comprise or consist of polytetrafluoroethylene (PTFE). In some embodiments, the filler **190** may be disposed around at least a portion of the tubular purge body **120** and the tubular electrical wire body **130**. In such embodiments, the filler may be configured to maintain a position of the tubular purge body relative to the tubular electrical wire body.

[0063] In some embodiments, the tubular purge body **120** also may comprise a plurality of layers **121**, **122**. In some embodiments, this plurality of layers may comprise an inner binder layer **122** and an outer jacket **121**. In some embodiments, the inner binder layer **122** of the tubular purge body may comprise or consist of polytetrafluoroethylene (PTFE) and the outer jacket **121** of the tubular purge body may comprise or consist of a thermoplastic polyurethane.

[0064] In some embodiments, the tubular purge body may be configured to extend through the first lumen from the distal end of the first tubular body to the proximal end of the first tubular body.

[0065] In some embodiments, the at least one tubular electrical wire body **130** may be configured to receive a plurality of electrical wires **140**, **145**. In some embodiments, filler **191** may be disposed around at least a portion of at least one electrical wire **140**, **145**. In some embodiments, each electrical wire may comprise copper, although the wire may be formed of other suitable materials. In some embodiments, each electrical wire comprises a conductive core **142** (which may comprise copper) surrounded by an insulating jacket **141**.

[0066] Referring to FIGS. 3C and 3D, a cross section of embodiments of a cable **102**, **103** can be seen. In some embodiments, at least one of the electrical wires **140**, **145**, **146** within the tubular electrical wire body **130** may be in electrical communication with a motor (*e.g.*, the motor of an axial or centrifugal blood pump). In some embodiments, each of the electrical wires within the tubular electrical wire body **130** may be in electrical communication with a motor. In some embodiments some of the electrical wires **140**, **145** within the tubular electrical wire body **130** may be in electrical communication with a motor, while one or more other electrical wires **147**, **148** within the tubular electrical wire body are in electrical communication with a different component or device, such as one or more sensors.

[0067] In some embodiments, the cable may also comprise a tubular optical fiber body **150** within the first lumen, the tubular optical fiber body having an inner surface **153** defining an optical fiber lumen therethrough, the optical fiber lumen configured to slidably receive an optical fiber. In some embodiments, the tubular optical fiber body may comprise or consist of polytetrafluoroethylene (PTFE). In some embodiments, the optical fiber lumen has an inner diameter of between 0.8 mm and 1.5 mm. In some embodiments, the tubular optical fiber body may have a wall thickness between 0.1 and 0.4 mm. As will be appreciated, the outer diameter of the tubular optical body may be the same as the tubular purge body and/or the tubular electrical body, although one or more of the tubular bodies may have a different diameter than the other.

[0068] Referring to FIG. 3E, a cross section of an embodiment of a cable **104** can be seen. In some embodiments, the cable may comprise a plurality of tubular electrical wire bodies **130**, **135**, including a first tubular electrical wire body **130** and a second tubular electrical wire body **135**. In some embodiments, at least one electrical wire body **147**, **148** in the second tubular electrical wire body are in electrical communication with a device or component (such as a sensor) other than the motor of a blood pump. In some embodiments, a plurality of electrical

wires may extend through each electrical wire lumen. In some embodiments, a number of electrical wires **145** in the first tubular electrical wire body **130** may be the same as the number of electrical wires **147**, **148** in the second tubular electrical wire body **135**. In some embodiments, a number of electrical wires **145** in the first tubular electrical wire body **130** may be different from a number of electrical wires **147**, **148** in the second tubular electrical wire body **135**. In some embodiments, the number of electrical wires in the first tubular electrical wire body **130** is 2-4, and number of electrical wires in the second tubular electrical wire body **135** is 3-5.

[0069] As will be appreciated, in some embodiments, each of the tubular purge body, the tubular electrical wire body, and the tubular optical fiber body may extend an entire length of the outer first tubular body (*e.g.*, between the tubular and proximal ends). In other embodiments, one or more of the tubular bodies may extend only partially through the outer first tubular body. For example, in some embodiments, the tubular purge body may exit the first tubular body at a position between the distal and proximal ends.

[0070] Controller

[0071] Referring to FIGS. 2A and 2B, in some embodiments, the controller **30** may be configured to control fluid flowing through the purge lumen, receive optical data through an optical fiber slidably positioned within the optical fiber lumen and control a motor through at least one electrical wire. In such embodiments, the controller may include at least one processor and at least one non-transitory computer readable medium containing instructions that, when executed, causes the at least one processor to control a pump, valve, or combination thereof to cause a fluid to flow through the purge lumen, receive optical data from an optical fiber, and control a motor (such as the rotational speed of a motor).

[0072] In some embodiments, the at least one processor is configured to cause adjustments to current flowing to a motor.

[0073] In some embodiments, the controller also controls a display **31** (such as a touchscreen display), and or may be configured to receive user input from one or more buttons, knobs, or other controls **32** for, *e.g.*, selecting modes of operation.

[0074] Overmold

[0075] Referring to FIG. 4A, in some embodiments, the cable may comprise a first overmold **200**. The first overmold **200** may be connected to a portion **210** of the first tubular body **110** at a location distal from a defined opening **205** extending from an outer surface **114** of the first

tubular body to an inner surface **113** of the first tubular body. The first overmold also may be connected to a portion **211** of both the tubular purge body **120** and the first tubular body **110** at a location proximal to the defined opening.

[0076] In some embodiments, the first overmold **200** may be configured to connect to a case. In some embodiments, at least one surface **216** may be recessed from an outer surface **215** of the first overmold. The depth of the recession may be configured to allow an outer surface of a case to be adjacent to and substantially coplanar with the outer surface **215** of the first overmold. In some embodiments, the first overmold may also have additional cutouts or depressions **217** that are configured to allow a case to be firmly connected to the first overmold (*e.g.*, via snap fittings, pressure fit, slidably connected, etc.). The case may then have respective features on an internal surface that allow it to interact with the cutouts or depressions **217**. In this manner, a case may be connected to the first overmold such that the case cannot twist apart, push apart, or pull apart from the first overmold.

[0077] Referring to FIG. 4B, in some embodiments, the cable may have a distal end **301** and a proximal end **302** and may comprise the first overmold **200** and a second overmold **300**. The second overmold **300** may be positioned proximal to the first overmold **200**, and an inner surface of the overmold **303** may be connected to the first tubular body **110**.

[0078] In some embodiments, the overmold may assist in creating branches in the fluid line. For example, in some embodiments, the overmold may allow one of the tubular bodies to exit the cable at a location between the proximal end and the distal end. For example, in some embodiments, the first tubular body may exit the first tubular body at or via the overmold.

[0079] Case

[0080] Referring to FIG. 5A, an embodiment of a cable operably connected to a connector **35**, the cable comprising a case **400** and overmolds **200**, **300**, can be seen. As depicted, in some embodiments, a case **400** may be configured to surround at least a portion of the first tubular body **10**, **11** proximal to the first overmold **200**, the case configured to connect to the first overmold **200** such that any component surrounded by the case cannot be twisted, pulled apart, or pushed apart.

[0081] In some embodiments, the case may be a two-part case having first and second bodies **410**, **420**. In some embodiments, each body may be formed of a polycarbonate material. In some embodiments, the case **400** is configured to contain a PSS assembly **430**. The two parts of the case may be configured to clamp together around an overmold **200**, the overmold

surrounding a portion of a first tubular body and a second tubular body (such as a tubular purge body), where the second tubular body may be connected to the PSS assembly 430.

[0082] In some embodiments, the case 400 defines a first port 401 surrounding a first overmold 200, a second port 402 for the first tubular body 11 distal from a second overmold 300 and proximal from the first overmold 200, and a third port 403 for allowing a fluid source to operably connect to the tubular purge body through an input connector 404.

[0083] In some embodiments, the first body 410 of the case may be in contact with a first portion 220 of the first overmold 200, and the second body 420 is in contact with a second portion 221 of the overmold.

[0084] As will be appreciated, the cable need not include an overmolded portion. Accordingly, in such embodiments, the first port 401 may surround only the cable 110 (see, *e.g.*, FIG. 7). As also shown in FIG. 7, the port may be connected to a first channel 440 for receiving the cable. The case also may include a second channel 442 for receiving a branch of the cable (*e.g.*, a fluid line connected to a purge cassette). As will be appreciated the channels may have any suitable arrangement (*e.g.*, straight and/or curved). In some embodiments, the first and second bodies of the case (as described herein) may cooperate to form the channel within which the cable and/or branches extend. The channels also may be formed in only one of the bodies. As will be further appreciated, in other embodiments, the channels may be housed in the case in other suitable manners.

[0085] Referring to FIGS. 5B-5D, the first body 410 of the case may be configured to connect to the second body 420 using a plurality of pins 423 and bosses 414, and a plurality of snap-fit connections 413. In some embodiments, a first body 410 may comprise a pin, a boss, or a combination thereof, and a plurality of depressed portions on an exterior surface of the second part, and a second body 420 may include either a pin, a boss, or a combination thereof, and at least one raised portion on an interior surface of the first part, where each pin or boss is configured to align with a boss or pin, respectively, on the opposite body, and the raised portion is configured to interact with each depressed portion such that the two parts cannot be pulled apart.

[0086] In some embodiments, the case can be connected by inserting one or more pins 423 on the second body into a corresponding boss 414 on the first body, and by one or more raised portions 426 on an internal surface 427 of the second part 425 interfacing with a plurality of depressions 414 on an external surface 415 of the first part.

[0087] As will be appreciated, other suitable fasteners may be used to couple the first and second bodies of the case together. The first and second bodies also may be connected via other suitable arrangements in other.

[0088] Referring to FIG. 6, it can be seen that in some embodiments, the two bodies **410**, **420** of the case are configured to contain a PSS assembly **425** and clamp around an overmold **200**.

[0089] As shown in FIGS. 7-11B, the case may have other suitable arrangements for housing the cable and PSS assembly. As shown in these examples (*e.g.*, FIG. 7), the first and second bodies may have similar constructions (*e.g.*, mirror images of each other) and cooperate to form the housing for receiving the PSS assembly and cable. In some embodiments (*see, e.g.*, FIGS. 11A and 11B, one body may include a cover that is attached to the second body.

[0090] In some embodiments, the case may include one or more windows **450** (*see, e.g.*, Fig. 11B) for viewing the PSS assembly, a portion of the cable, and/or the overmold. In some embodiments, the windows may be formed in a single body (*see, e.g.*, FIGS. 11A and 11B), while in other embodiments, the first and second bodies may cooperate to form one or more windows in the case.

[0091] In some embodiments, the case may include one or more doors through which a clinician may access cables, cassettes, or other components housed within the cable.

[0092] As shown in FIGS. 7-11B, the PSS assembly and cable may have any suitable arrangement in the case. For example, in some embodiments, the PSS assembly may be positioned on top of the cable (*see, e.g.*, FIGS. 6 and 7). In such embodiments, as seen in FIG. 7, the X-Y plane of the PSS assembly does not intersect with a central axis of the first tubular body. That is, a bottom surface of the PSS assembly may be directed towards the first tubular body. In some embodiments, the cases may be configured to have two parts that each is configured to conform with either a first or second portion (*e.g.*, a left or right portion) of the PSS assembly.

[0093] In other embodiments (*see, e.g.*, FIG. 8), the cable and the PSS assembly may be placed side by side. As seen in this view, in some embodiments, the X-Y plane of the PSS assembly may intersect with a central axis of the first tubular body. That is, a left or right surface of the PSS assembly may be directed towards the first tubular body, and the bottom surface may be orthogonal to the central axis. In some embodiments, the cases may be configured to have two parts that each conform with either a bottom portion or a top portion of the PSS assembly.

[0094] In other embodiments (*see, e.g.*, FIGS. 9 and 10), the PSS assembly may be folded around the cable. For example, as seen in these views, in some embodiments, the PSS assembly is not arranged in a linear fashion. In some embodiments, a first portion of the PSS assembly

may be present on one side of the first tubular body, and a second portion of the PSS assembly may be present on a second side of the first tubular body.

[0095] The case also may be configured such that a majority of the PSS assembly is partially encompassed by a first part of the case, and a second part of the case is substantially acting as a lid or cover when the two parts are combined (see FIGS. 11A and 11B).

[0096] In some embodiments, the case may include a first region to include a cassette attachable to the fluid line.

[0097] In some embodiments, the case may be arranged to retain a portion of cable extending from the case. In some embodiments, the cable may be removable attachable to the case for extending between the case and controller. For example, as shown in FIG. 12, the case may include a holder **444** around which a length of cable may be wrapped. As will be appreciated, the holder may be removably attached to one of the bodies, may be fixedly attached thereto, or may be integrally formed therewith. As shown in FIGS. 13A and 13B, the case also may include a compartment **446** for holding a length of cable. For example, a spool of cable **447** may be held in the compartment in some embodiments. In some embodiments, the cable **448** that forms the spool of cable **447** may extend from an input connector **430**. In some embodiments, the cable that forms the spool of cable does not extend from an input connector.

[0098] The case also may have other stiffening and/or reinforcement features (*e.g.*, crush ribs). In some embodiments, the cable and/or PSS may be positioned at or near the ribs. In some embodiments, the crush ribs may be positioned around a portion of the cable and/or PSS when the case is assembled.

[0099] The overmold, as described herein, may surround a portion of a first tubular body **110** and a second tubular body (such as tubular purge body **120**). The first part **410** may be configured to connect with a depression or groove **217** (*see, e.g.*, FIG. 6) in the overmold, to prevent the case from twisting, pushing, or pulling apart. A proximal end **125** of the second tubular body (here, tubular purge body **120**) may be connected to a PSS assembly, which may comprise an input connector **430**. The input connector may be removably connectable to a fluid source.

[0100] A distal end of the cable **10** may be connected to a handle (not shown). The handle may comprise, *e.g.*, circuitry protected by an outer housing. A proximal end of the cable may be directly or indirectly connected to one or more connectors **35** and through the connector **35** to a controller. The connector may be configured to provide electrical and optical connections to the controller.

[0101] Although the case is shown and described as being a two-part case, in other embodiments, the case may include three or more bodies that cooperate to form a compartment for holding the PSS and the cable, and in some embodiments, an overmold.

[0102] Those skilled in the art will recognize or be able to ascertain using no more than routine experimentation many equivalents to the specific embodiments of the invention described herein. Such equivalents are intended to be encompassed by the following claims.

What is claimed is:

1. A cable arranged to operably connect a blood pump to a controller, the cable comprising:
 - a first tubular body having a distal end and a proximal end, the first tubular body defining a first lumen therethrough,
 - a tubular purge body disposed within the first lumen and extending along at least a portion of a length of the first lumen, the tubular purge body defining a purge lumen arranged to transfer a fluid therethrough; and
 - at least one tubular electrical wire body disposed within the first lumen, each tubular electrical wire body defining an electrical wire lumen therethrough for receiving one or more electrical wires.
2. The cable according to claim 1, wherein the first tubular body comprises a plurality of layers.
3. The cable according to claim 2, wherein the plurality of layers comprises an inner binder layer and an outer jacket.
4. The cable according to claim 3, wherein the inner binder layer of the first tubular body comprises polytetrafluoroethylene (PTFE) and the outer jacket of the first tubular body comprises a thermoplastic polyurethane.
5. The cable according to any one of claims 1-4, further comprising filler within the first lumen.
6. The cable according to claim 5, wherein the filler is disposed around at least a portion of the tubular purge body and the tubular electrical wire body.
7. The cable according to claim 5 or 6, wherein the filler comprises polytetrafluoroethylene (PTFE).
8. The cable according to any one of claims 1-7, wherein the tubular purge body comprises a plurality of layers.

9. The cable according to claim 8, wherein the tubular purge body comprises an inner binder layer and an outer jacket.
10. The cable according to claim 9, wherein the inner binder layer of the tubular purge body comprises polytetrafluoroethylene (PTFE) and the outer jacket of the tubular purge body comprises a thermoplastic polyurethane.
11. The cable according to any one of claim 1-10, wherein a proximal portion of the tubular purge body is operably connected to an input connector, the input connector configured to provide a sterile attachment to a fluid source.
12. The cable according to claim 11, wherein the fluid source is removably attachable from the input connector.
13. The cable according to claim 11 or 12, wherein the proximal portion of the tubular purge body is connected to a pressure storage set (PSS) assembly comprising the input connector.
14. The cable according to any one of claims 1-13, wherein the first tubular body comprises an outer surface defining a first opening extending to an inner surface of the first tubular body, the inner surface defining the first lumen, the tubular purge body configured to enter the first lumen through the first opening.
15. The cable according to any one of claims 1-14, wherein the tubular purge body is configured to extend through the first lumen from the distal end of the first tubular body to the proximal end of the first tubular body.
16. The cable according to claim 1-15, wherein the at least one tubular electrical wire body is configured to receive at least one electrical wire in electrical communication with a motor.

17. The cable according to any one of claims 1-16, wherein the at least one tubular electrical wire body comprises a plurality of tubular electrical wire bodies, including a first tubular electrical wire body and a second tubular electrical wire body.
18. The cable according to claim 17, wherein at least one electrical wire extending through the second tubular electrical wire body is in electrical communication with a sensor.
19. The cable according to claim 17 or 18, wherein a number of electrical wires in the first tubular electrical wire body is different from a number of electrical wires in the second tubular electrical wire body.
20. The cable according to claim 19, wherein the number of electrical wires in the first tubular electrical wire body is 2-4, and number of electrical wires in the second tubular electrical wire body is 3-5.
21. The cable according to any one of claims 1-20, wherein a plurality of electrical wires extend through the electrical wire lumen of one or more of the at least one tubular electrical wire bodies.
22. The cable according to any one of claims 1-21, wherein a plurality of electrical wires extend through each electrical wire lumen.
23. The cable according to any one of claims 1-22, wherein each of the one or more electrical wires comprises copper.
24. The cable according to any one of claims 1-23, wherein filler is disposed around at least a portion of at least one electrical wire.
25. The cable according to any one of claims 1-24, further comprising a tubular optical fiber body within the first lumen, the tubular optical fiber body defining an optical fiber lumen therethrough.
26. The cable according to claim 25, wherein the tubular optical fiber body comprises polytetrafluoroethylene (PTFE).

27. The cable according to any of claims 1-26, wherein the cable extends from a handle to a controller.
28. The cable according to claim 27, wherein the controller is configured to control a fluid flowing through the purge lumen, receive optical data through an optical fiber slidably positioned within the optical fiber lumen, and control a motor through at least one electrical wire.
29. The cable according to any one of claims 1-28, further comprising a first overmold, the first overmold connected to a portion of the first tubular body at a location distal to a defined opening extending from an outer surface of first tubular body to an inner surface of the first tubular body, and connected to a portion of both the tubular purge body and the first tubular body at a location proximal to the defined opening.
30. The cable according to claim 29, further comprising a second overmold, the second overmold connected to a portion of the first tubular body at a location proximal from the first overmold.
31. The cable according to claim 29 or 30, further comprising a case configured to surround at least a portion of the first tubular body proximal to the first overmold, the case configured to connect to the first overmold such that any component surrounded by the case cannot be twisted, pulled apart, or pushed apart.
32. The cable according to claim 31, wherein the case is a two-part case.
33. The cable according to claim 32, wherein each part of the two-part case comprises a polycarbonate.
34. The cable according to claim 32 or 33, wherein a first part of the two-part case is configured to connect to a second part of the two-part case by inserting one or more pins on the second part into a corresponding boss on the first part, and by one or more raised portions on an internal surface of the second part interfacing with a plurality of depressions on an external surface of the first part.

35. The cable according to any of claims 31-34, wherein the case defines an output port surrounding a first overmold, an input port for the first tubular body distal from a second overmold and proximal from the first overmold, and an input port for allowing a fluid source to operably connect to the tubular purge body through an input connector.

36. A system comprising:
a controller;
a pump; and
a cable according to any one of claims 1-35, the cable operably connecting the pump to the controller.

37. The system according to claim 36, wherein the cable extends from a handle to the controller.

38. An overmold for a first tubular body defining a first lumen therethrough, the first tubular body having a second tubular body within the first lumen, the second tubular body defining a second lumen therethrough, the second tubular body configured to enter the first lumen through an opening defined by an outer surface of the first tubular body, the opening extending to the first lumen, the overmold comprising:

a distal portion connected to a portion of the first tubular body at a location distal to the defined opening; and

a proximal portion connected to a portion of both the first tubular body and the second tubular body at a location proximal to the defined opening, the proximal portion configured to connect to a case such that the case cannot twist, push, or pull apart from the overmold.

39. The overmold according to claim 38, wherein the case is a two-part case comprising a first part and a second part, wherein the first part is in contact with a first portion of the overmold, and the second part is in contact with a second portion of the overmold.

40. The overmold according to claim 38 or 39, wherein the first tubular body comprises a plurality of layers.

41. The overmold according to claim 40, wherein the plurality of layers comprises an inner binder layer and an outer jacket.
42. The overmold according to claim 41, wherein the inner binder layer of the first tubular body comprises polytetrafluoroethylene (PTFE) and the outer jacket of the first tubular body comprises a thermoplastic polyurethane.
43. The overmold according to any one of claims 38-42, further comprising filler within the first lumen.
44. The overmold according to claim 43, wherein the filler is disposed around at least a portion of the second tubular body and at least one additional tubular body extending through at least a portion of the first lumen.
45. The overmold according to claim 43 or 44, wherein the filler comprises polytetrafluoroethylene (PTFE).
46. The overmold according to any one of claims 38-45, wherein the second tubular body comprises a plurality of layers.
47. The overmold according to claim 46, wherein the second tubular body comprises an inner binder layer and an outer jacket.
48. The overmold according to claim 47, wherein the inner binder layer of the second tubular body comprises polytetrafluoroethylene (PTFE) and the outer jacket of the second tubular body comprises a thermoplastic polyurethane.
49. The overmold according to any one of claim 38-48 wherein a proximal portion of the second tubular body is operably connected to an input connector, the input connector configured to provide a sterile attachment to a fluid source.
50. The overmold according to claim 49, wherein the fluid source is removably attachable from the input connector.

51. The overmold according to claim 49 or 50, wherein the proximal portion of the second tubular body is connected to a physiological saline solution (PSS) assembly comprising the input connector.
52. The overmold according to any one of claims 38-51, further comprising at least one additional tubular body extending through the first lumen from a proximal end to a distal end, each additional tubular body defining a lumen extending therethrough.
53. The overmold according to any one of claims 52, wherein the at least one additional tubular body comprises a plurality of additional tubular bodies, including a first additional tubular body defining a first additional lumen and a second additional tubular body defining a second additional lumen.
54. The overmold according to claim 53, wherein a number of electrical wires in the first additional tubular body is different from a number of electrical wires in the second additional tubular body.
55. The overmold according to claim 54, wherein the number of electrical wires in the first additional tubular body is 2-4, and number of electrical wires in the second additional tubular body is 3-5.
56. The overmold according to claim 52 or 53, wherein at least one electrical wire extends through one or more of the at least one additional tubular bodies.
57. The overmold according to claim 56, wherein at least one electrical wire extending through one or more of the at least one additional tubular bodies is in electrical communication with a sensor.
58. The overmold according to any one of claims 52-57, wherein a plurality of electrical wires extend through one of the at least one additional tubular bodies.
59. The overmold according to claim 58, wherein a plurality of electrical wires extend through each additional tubular body.

60. The overmold according to any one of claims 56-59, wherein each electrical wire comprises copper.
61. The overmold according to any one of claims 52-60, wherein the at least one additional tubular body comprises a tubular optical fiber body defining an optical fiber lumen configured to slidably receive an optical fiber therethrough.
62. The overmold according to any of claims 38-61, wherein the first tubular body extends from a handle to a controller, the overmold being positioned between the handle and the controller.
63. The overmold according to claim 62, wherein the controller is configured to control a fluid flowing through a purge lumen, receive optical data through an optical fiber slidably positioned within the optical fiber lumen, and control a motor through at least one electrical wire.
64. A two-part case configured to contain a PSS assembly and clamp around an overmold, the overmold surrounding a portion of a first tubular body and a second tubular body, the second tubular body being connected to the PSS assembly, the two-part case comprising:
- a first part comprising either a pin, a boss, or a combination thereof, and a plurality of depressed portions on an exterior surface of the first part; and
 - a second part comprising a pin, a boss, or a combination thereof, and at least one raised portion on an interior surface of the second part;
- wherein each pin or boss is configured to align with a boss or pin, respectively, on an opposite part, and wherein the at least one raised portion is configured to interact with each depressed portion such that the first part and the second part cannot be pulled apart.